US009588186B2

(12) **United States Patent**
Arnold et al.

(10) **Patent No.: US 9,588,186 B2**
(45) **Date of Patent: Mar. 7, 2017**

(54) **MECHANICAL MEASUREMENT OF STATE OF HEALTH AND STATE OF CHARGE FOR INTERCALATION BATTERIES**

(71) Applicants: **Craig B. Arnold**, Princeton, NJ (US); **John Cannarella**, Wayne, NJ (US)

(72) Inventors: **Craig B. Arnold**, Princeton, NJ (US); **John Cannarella**, Wayne, NJ (US)

(73) Assignee: **THE TRUSTEES OF PRINCETON UNIVERSITY**, Princeton, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 534 days.

(21) Appl. No.: **14/052,668**

(22) Filed: **Oct. 11, 2013**

(65) **Prior Publication Data**

US 2014/0107949 A1 Apr. 17, 2014

Related U.S. Application Data

(60) Provisional application No. 61/712,316, filed on Oct. 11, 2012.

(51) **Int. Cl.**
G01R 31/36 (2006.01)
G01L 5/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G01R 31/3679*** (2013.01); ***G01L 5/00*** (2013.01); *G01R 31/3606* (2013.01); *G01R 31/3651* (2013.01)

(58) **Field of Classification Search**
USPC 702/42
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0286739 A1* 11/2012 O'Brien, Jr. H01M 2/1077 320/134
2013/0122332 A1* 5/2013 van Lammeren . H01M 10/4257 429/61
2013/0323554 A1 12/2013 Heubner et al.
2014/0092375 A1* 4/2014 Raghavan G01L 1/246 356/32

FOREIGN PATENT DOCUMENTS

DE 10 2012 209 271 * 12/2013 ..... H01M 10/48

OTHER PUBLICATIONS

Venkatasailanathan Ramadesigan, Modeling and Simulation of Lithium-Ion Batteries from a Systems Engineering Perspective, Jan. 26, 2012, Journal of the Electrochemical Society, 159 (3) R31-R45 (2012).*

* cited by examiner

Primary Examiner — Tung Lau
(74) *Attorney, Agent, or Firm* — Meager Emanuel Laks Goldberg & Liao, LLP

(57) **ABSTRACT**

A battery management system for use with a battery under test is disclosed. The system includes a container configured to hold the battery. The system also includes a stress/strain sensor. The container is configured to hold the battery in fixed relationship with respect to the stress/strain sensor. A processor is coupled to the stress/strain sensor, the processor being configured to measure the stress/strain on the battery and determine the state of health (SOH) of the battery based on the measured stress/strain and previously stored SOH relationship data for the battery. The processor may be configured to determine a state of charge (SOC) of the battery based on the measured stress/strain, the SOH of the battery and previously stored SOC relationship data for the battery.

18 Claims, 4 Drawing Sheets

